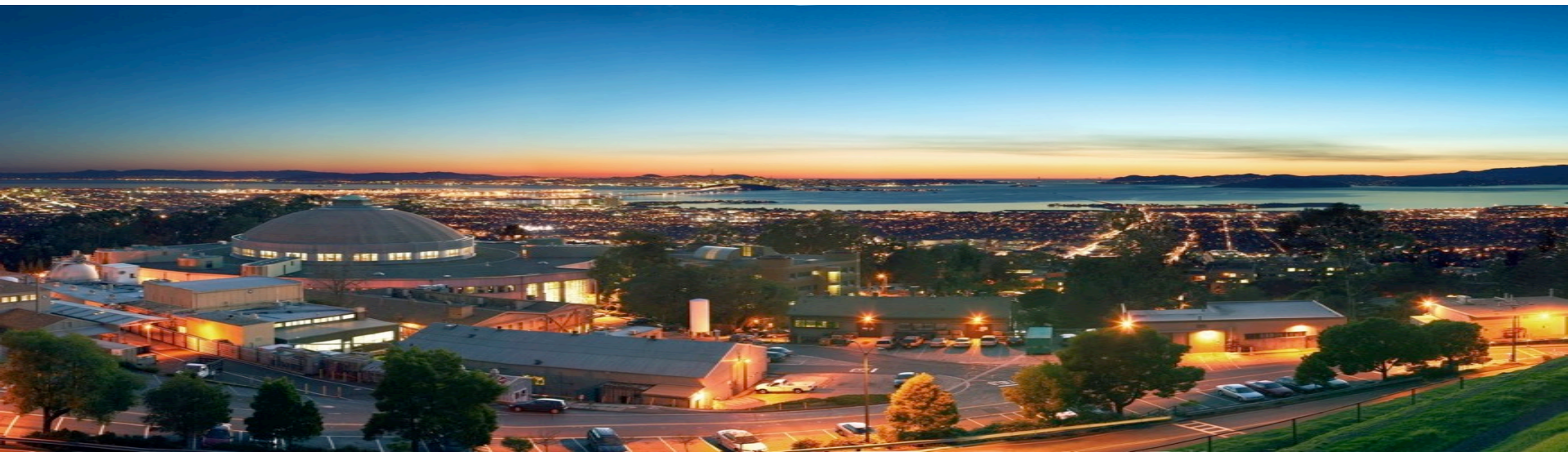


# Biosciences for for an Expanding Bioeconomy

Mary E. Maxon, Ph.D.  
Associate Laboratory Director for Biosciences  
Lawrence Berkeley National Laboratory



# Biosciences at a Glance

## 3 Scientific Divisions and a User Facility

- Biological Systems and Engineering
- Environmental Genomics and Systems Biology
- Molecular Biophysics and Integrated Bioimaging
- Joint Genome Institute

670+ staff and 733 affiliates

\$180+M in funding in FY2018

Scientific	212
Technical	147
Operations	66
Faculty	68
PostDoc	83
Graduate	29
Undergraduate	67
Affiliates	733



# Berkeley Lab's Strategic Biosciences Area

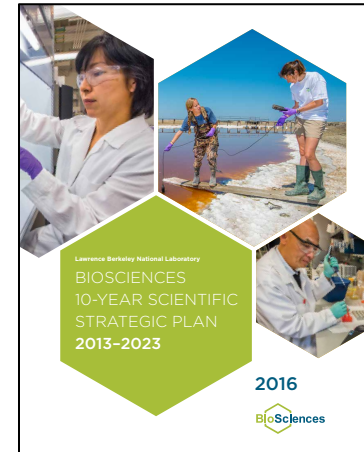
10-Year Biosciences Strategic Plan released in 2013

- Energy
- Environment
- Health
- Biomanufacturing
- Technologies

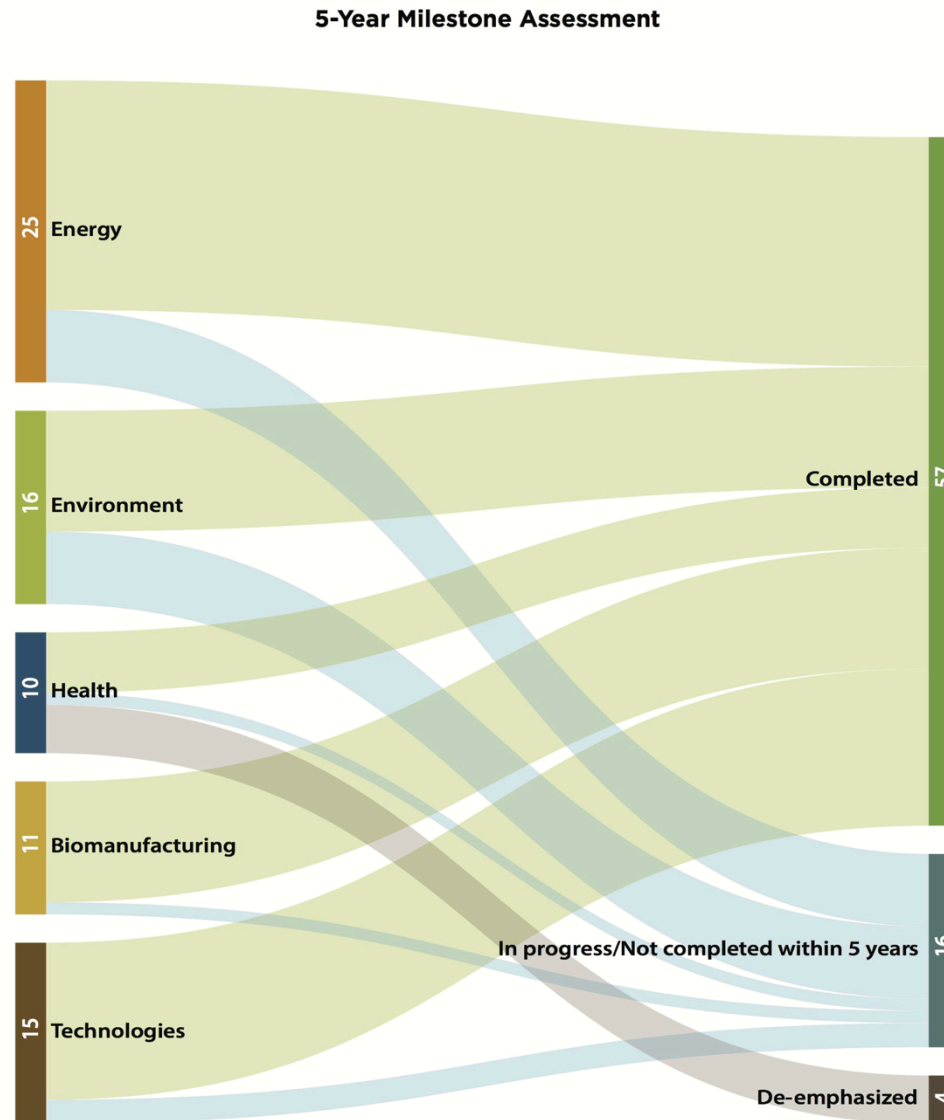
BSP is structured for implementation

- Progress can be measured
  - Five 10-year goals
  - 10-year metrics of success
  - 5-year milestones

Progress report completed in May 2018



# Biosciences Completed 74% of Our Milestones



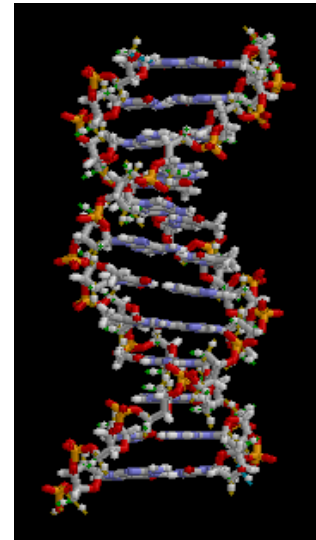


# Pillars of the U.S. Bioeconomy

## BIOMASS

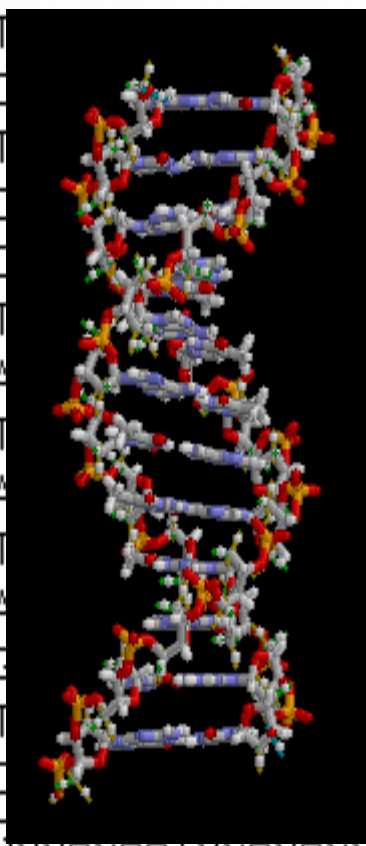


## BIOTECHNOLOGY



“BIO” = DNA

GACAGTAGAGAGCTATTGTGTAATTCAGGCTCAGCATTTCATCGACCTTTCTGTGTGAATATTGTGCTAATGCA  
TCTCGTCCGTAACGATCTGGGGGGCAAACCGAATATCCGTATTCTCGTCCTACGGGTCCACAATGAGAAAGTCC  
TGC GCGTGATCGTCAGTTAAGTTAAATTAATTCAGGCTACGGTAAACTTGTAGTGAGCTAAGAATCACGGGAATC  
ACGGGTTTCGCTACAGATGAACTGAATTTATACACGGACAACCTCATCGCCCATTTGGGCGTGGGCACCGCAGATCA  
AAAGTGGCAGATTAGGAGTGCTTGATCAGGTTAGCAGGTGGACTGTATCCAACAGCGCATCAAACCTTCAATAAA  
CCAAAGCGTTGTAGTGGTCTAAGCACCCCTTATCGTTAGCGTAGTACAACCCTTCCCCCTTG  
AGGTGCGACATGGGGCCAGTTAGCCTGCCCTACGTTCAATAAGAGGGGCTCTACAGCGCCGC  
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AGCTGACACGCAAGGGTCAACAATAATTTCTGAACGACTGTCTTTGCAAGAACCAACTGGG  
CTTAGATTCGCGTCCTAACGTAGTGAGGGCATCAGGCATGAGAAACCGACGTCGAGTCTA  
CACACGAGTTGTAAACAACCTTGATTGCTATCAAGGATCTCCTACATCAAAGACTACTGGGCG  
ATCTGGATCCGAGTCAGAAATACGAGTTAAGACCGGTGAAAACACGTGCCATGGGTTCGCT  
AGACCGTAGTCAGAAGTGTGGCGCGCTATTGGAGTATACAGAATTGCTCTTCTACGACGTA  
AGGAGCTCGGTCCCCAATGCACGCCAAAAA  
CTATTATCCATCCGAACGTTGAACCTACTTGTGCTGTGGATCTTAACGGCCACATTCTTA  
CGGCTGTGGATCTTAACGGCCACATTCTTA  
ACTAAGTTATCCAGATCAAGGTTTGAACGGCTGTTTCAAGGCCTCTGCTTTGGTATCACT  
CTAGGTATTCACGCAACCGTCGTAACATGCAAGACTACCCTATGGATTCTTGGAGCGCG  
GGTATTATTAGCAAGACAATAAAGGACATTGCACAGAGACTTATTAGAATTCAACAAACAGGATCATATCATGCG  
GTGTTGGGTCGGGCAAGTCCCCGAAGCTCGGCCAAAAGATTGCCATGGAACCGTCTGGTCCTGTTAGCGTGTAC  
GCCTGCTCCTGTTCCGGGTACCATAGATAGACTGAGATTGCGTCAAAAAATTGCGGCGAAAAATAGAGGGGCTCCT  
GTAGAAATACCAGACTGGGGAATTTAAGCGCTTTCCACTATCTGAGCGACTAAACATCAACAAATGCGTCTACT  
CGAATCCGCAGTAGGCAATTACAACCTGGTTTCAGATCACTGGTTAATCAGGGGATGTCTTCATAAGATTATACTTC



# “Reading” and “Writing” DNA

## “Reading” DNA

Human Genome Project

1990-2000

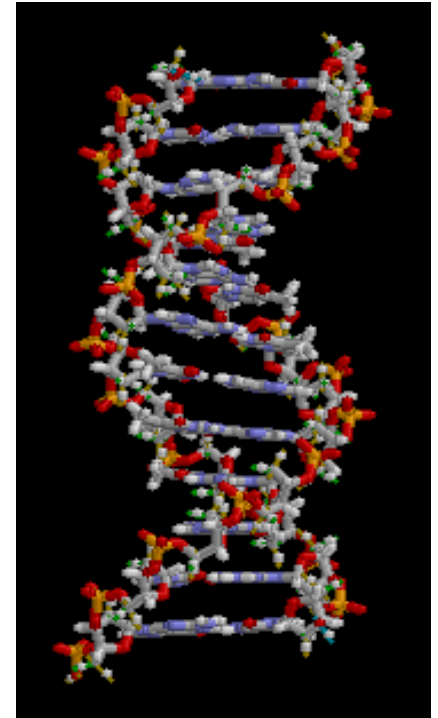
## “Writing” DNA

No federal initiative

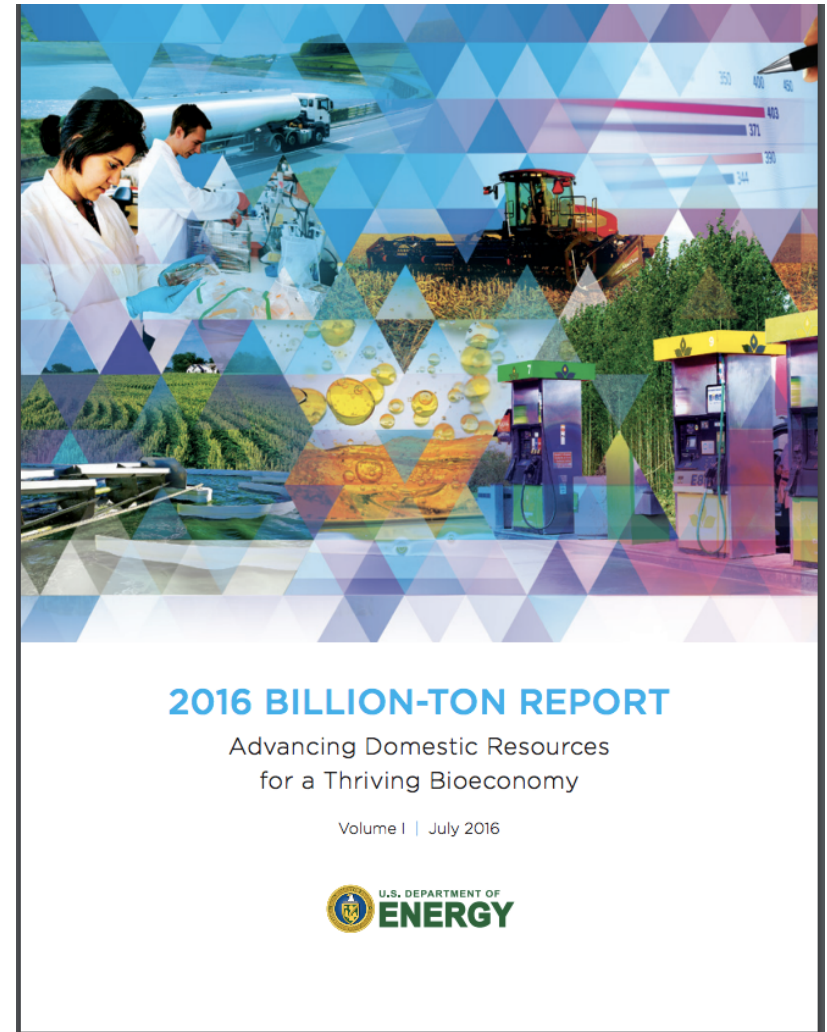
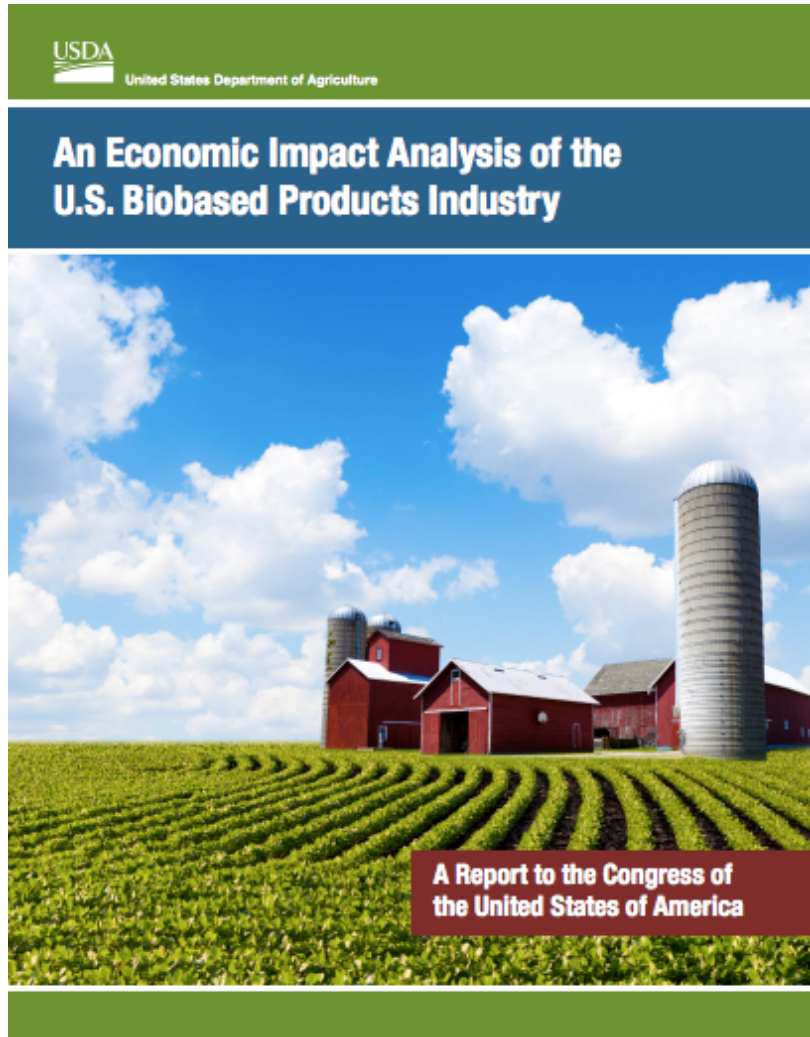
Today, \$1 buys:

Reading DNA = 500,000 “letters”

Writing DNA = 10 “letters”



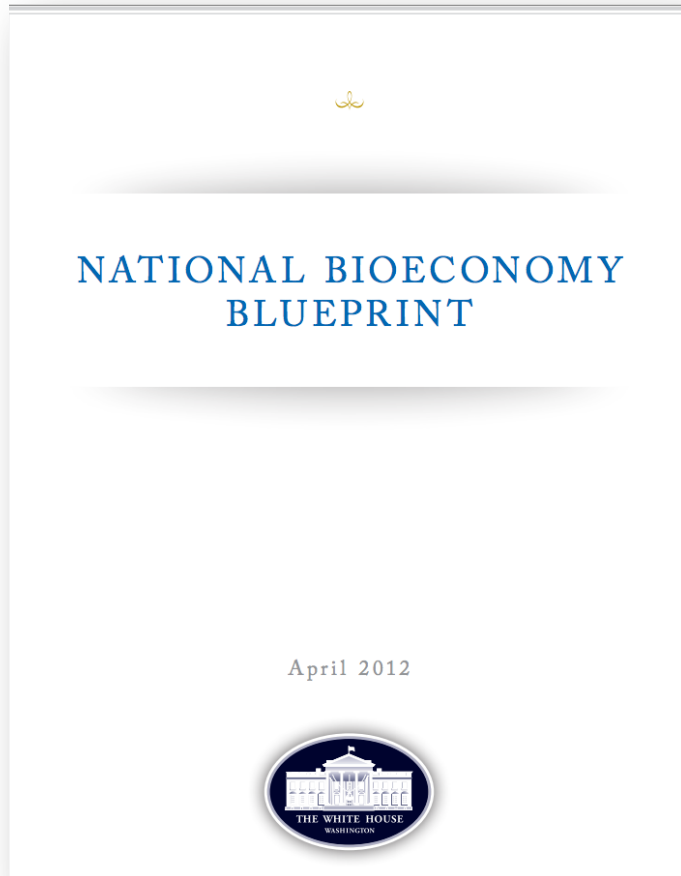
# U.S. Bioeconomy-related Assessments (non-biomedical)



**\$369 Billion**  
**4 Million jobs**



# Policy for the U.S. Bioeconomy 2012



2016

>\$350B revenues from GMOs  
>10% annual growth

**Support R&D investments that will provide the foundation for the future bioeconomy.**



Facilitate the transition of bioinventions from research lab to market, including an increased focus on translational and regulatory sciences.

**Develop and reform regulations to reduce barriers, increase the speed and predictability of regulatory processes, and reduce costs while protecting human and environmental health.**



Update training programs and align academic institution incentives with student training for national workforce needs.

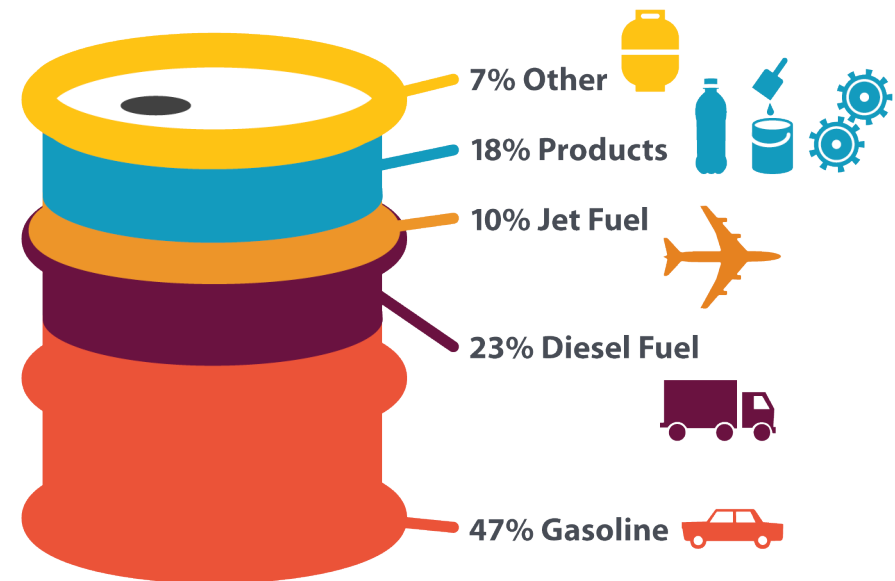
**Identify and support opportunities for the development of public-private partnerships and precompetitive collaborations—where competitors pool resources, knowledge, and expertise to learn from successes and failures.**



# In the U.S. Petroleum Is the Primary Source for Transportation Fuels and Chemicals



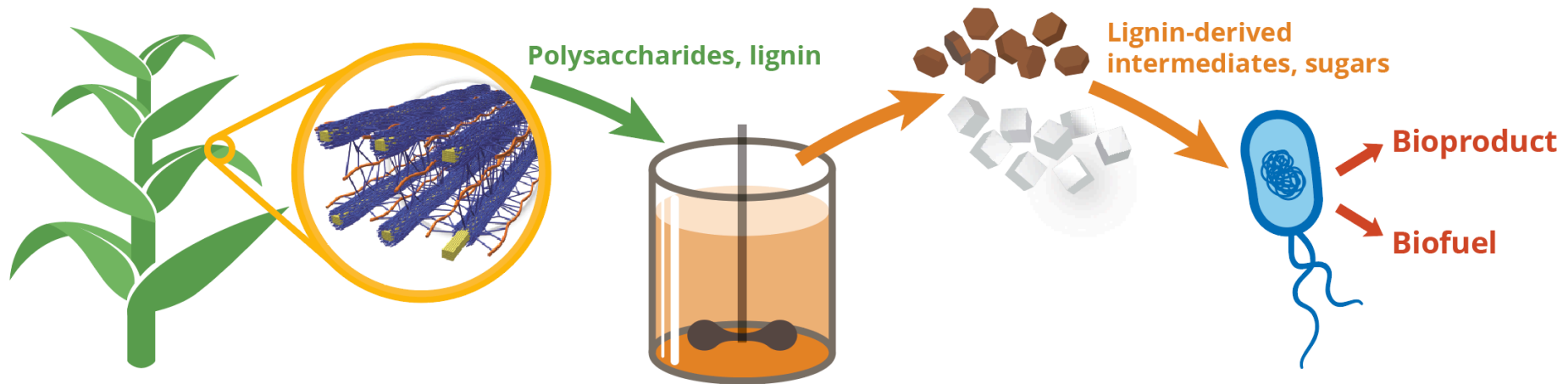
## Petroleum products made from a barrel of crude oil



Source: U.S. Department of Energy



# Biomass + Biotechnology: engineering of plants and microbes drives the U.S. bioeconomy



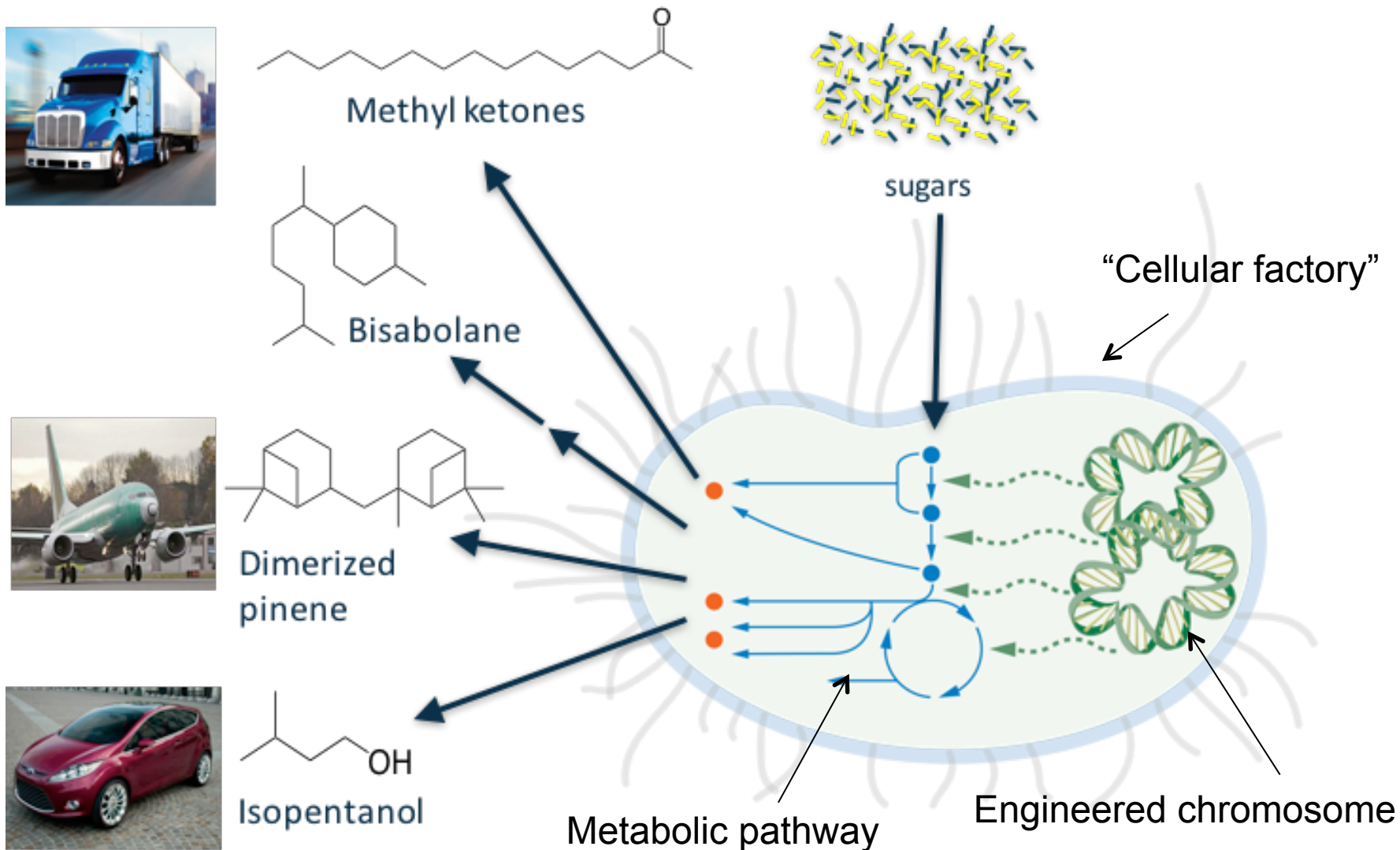
Create crops with desired characteristics:

- Increased sugar
- Decreased lignin
- Drought tolerance
- Reduced dependence on fertilizers

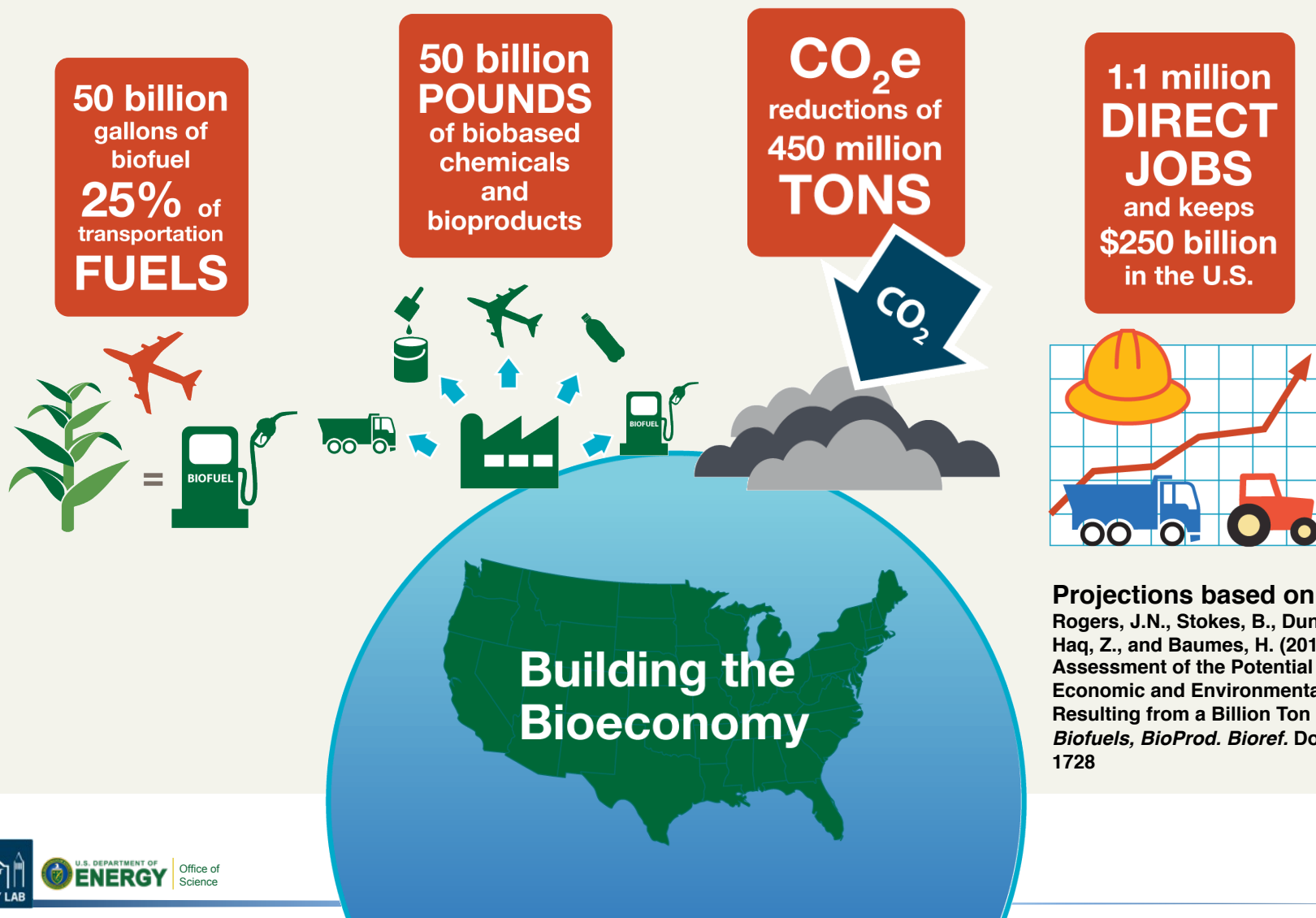
Create microbial production hosts:

- Genetic pathways for desired products
- Designed features for fermenter performance

# Example: engineered organisms for biofuels



# A billion tons of biomass has the potential to produce...



# California Bioeconomy: Biomass data

2017 data from the Billion Ton report



**Only 15% of available biomass is used!**

# California “Gold”: Diverse biomass resources

- “F.O.G.” : fats, oils, greases
- Small, localized sources: breweries, etc.
- Municipal solid waste
- Animal waste from livestock ranches
- Specialty crop agricultural waste
- Forest waste

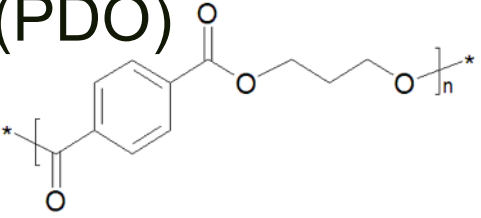
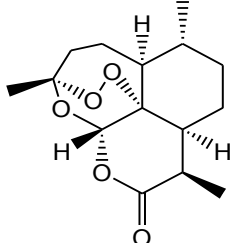


# The challenge: engineering biology remains slow





# The challenge: cost and time to market

Molecule	Company	Cost	Time
1,3-Propanediol (PDO) 	DuPont - Tate & Lyle	>\$120M	15 years
Artemisinin 	UC Berkeley, Amyris, Sanofi	>\$50M	10 years

Possible savings of *billions* of dollars by reducing development time of products, reducing energy intensity and increasing carbon efficiency

# Industry needs: de-risk technologies and decrease time to market



ABOUT

CAPABILITIES

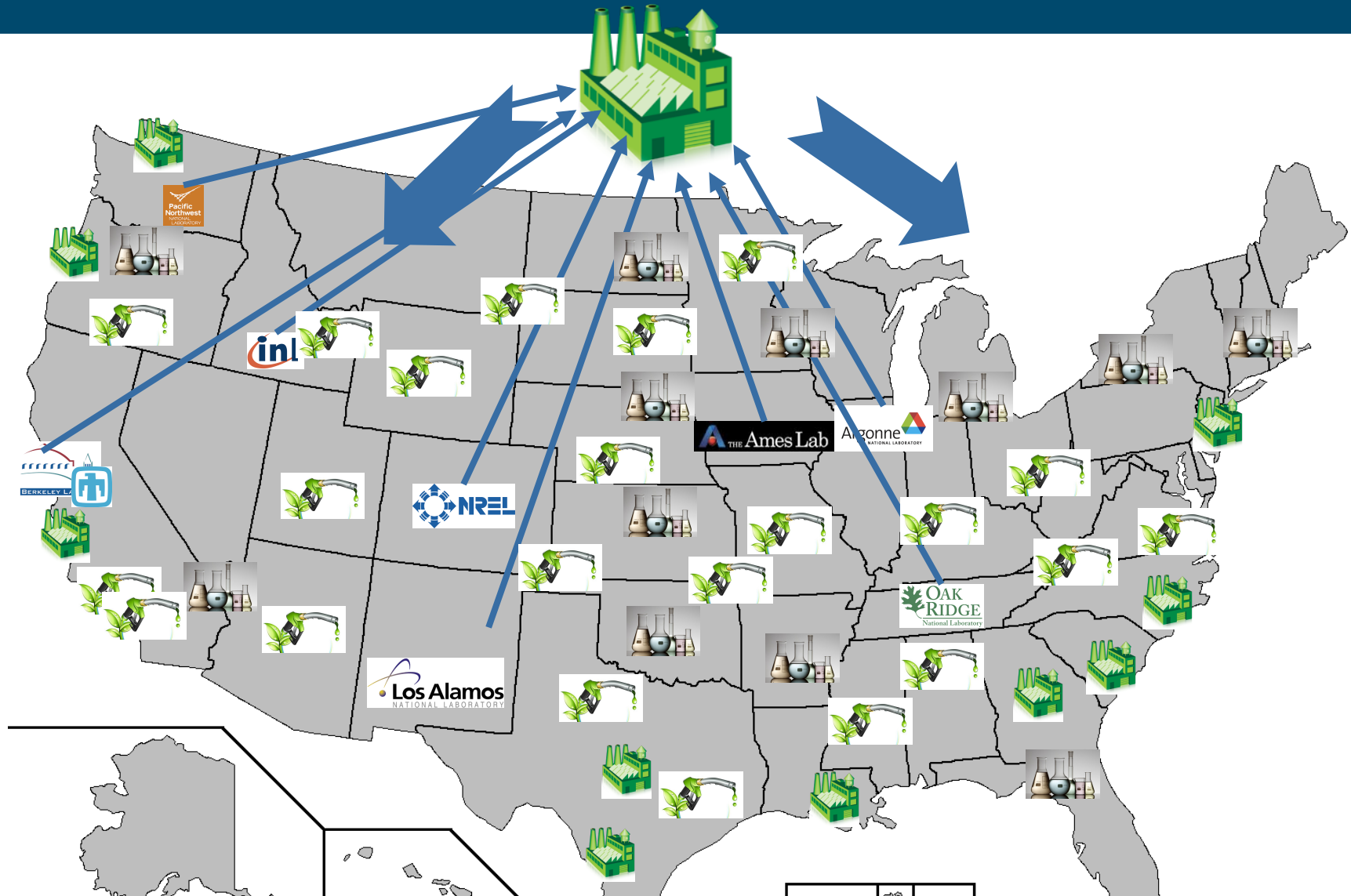
PEOPLE

WORK WITH US



- Established in Fiscal Year 2016, a consortium of 8 national laboratories
- Aimed to address shared industry research needs:
  - Accelerate engineering biology and process improvements for biomanufacturing using **automation** and **machine learning**
  - Develop and make publicly available standards, tools, technologies
- Democratize “writing DNA”
- \$20M in Fiscal Year 2019 budget; total of \$64.5M

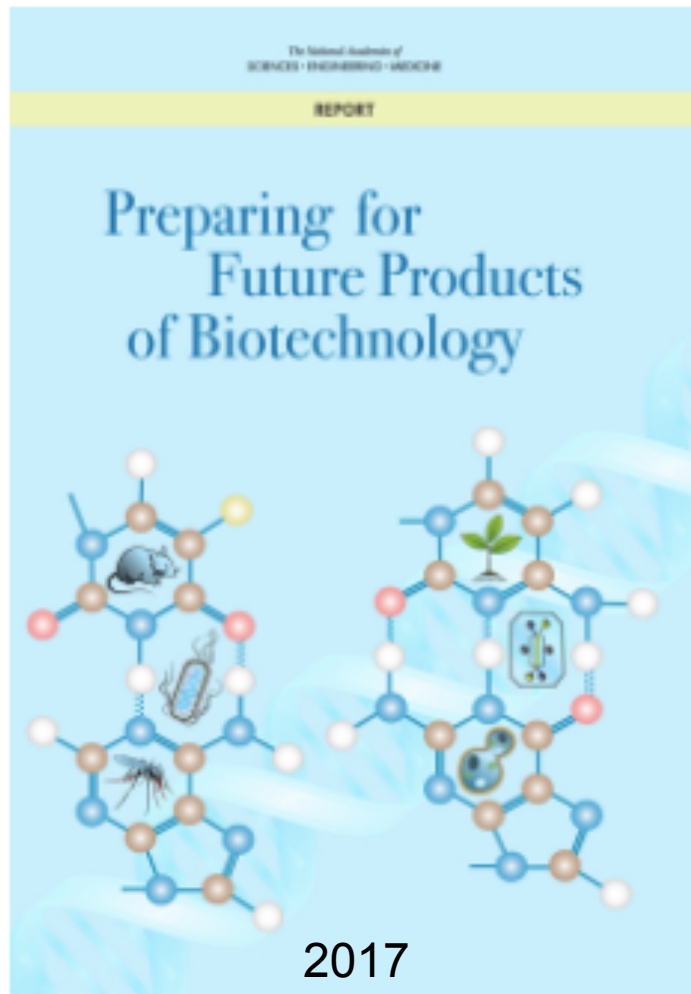
# A Distributed Agile BioFoundry: 8 National Laboratories



## 1986 Coordinated Framework for the Regulation of Biotechnology

Updated in 2017

# Regulation of products of biotechnology



## Biotechnology Regulatory Authorities:

- **US Department of Agriculture:**  
engineered plants/crops (Plant Protection Act)
- **Food & Drug Administration:**  
engineered animals (Food, Drug & Cosmetic Act)
- **Environmental Protection Agency:**  
engineered micro-organisms (Toxic Substances Act)

Commissioned an independent study by the U.S. National Academies for horizon-scanning to prepare for new products of biotechnology

*The National Academies of*

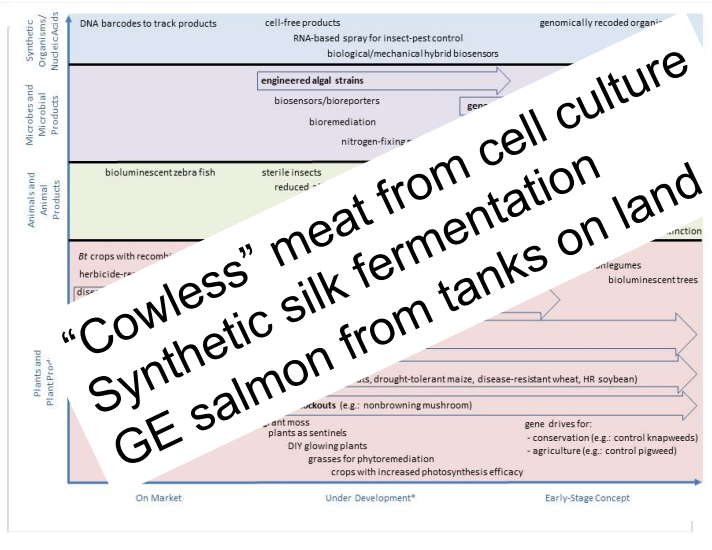
SCIENCES • ENGINEERING • MEDICINE

# What is a Biotechnology Product?

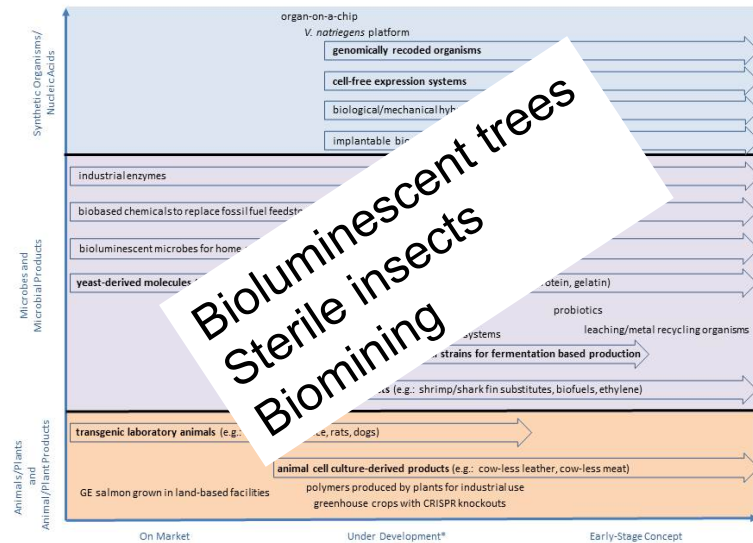
Products developed through genetic engineering or genome engineering or the targeted or *in vitro* manipulation of genetic information of organisms, including plants, animals, and microbes

Includes products where the engineered DNA molecule is itself the “product” as in an engineered molecule used as a DNA information-storage medium

## Contained use products



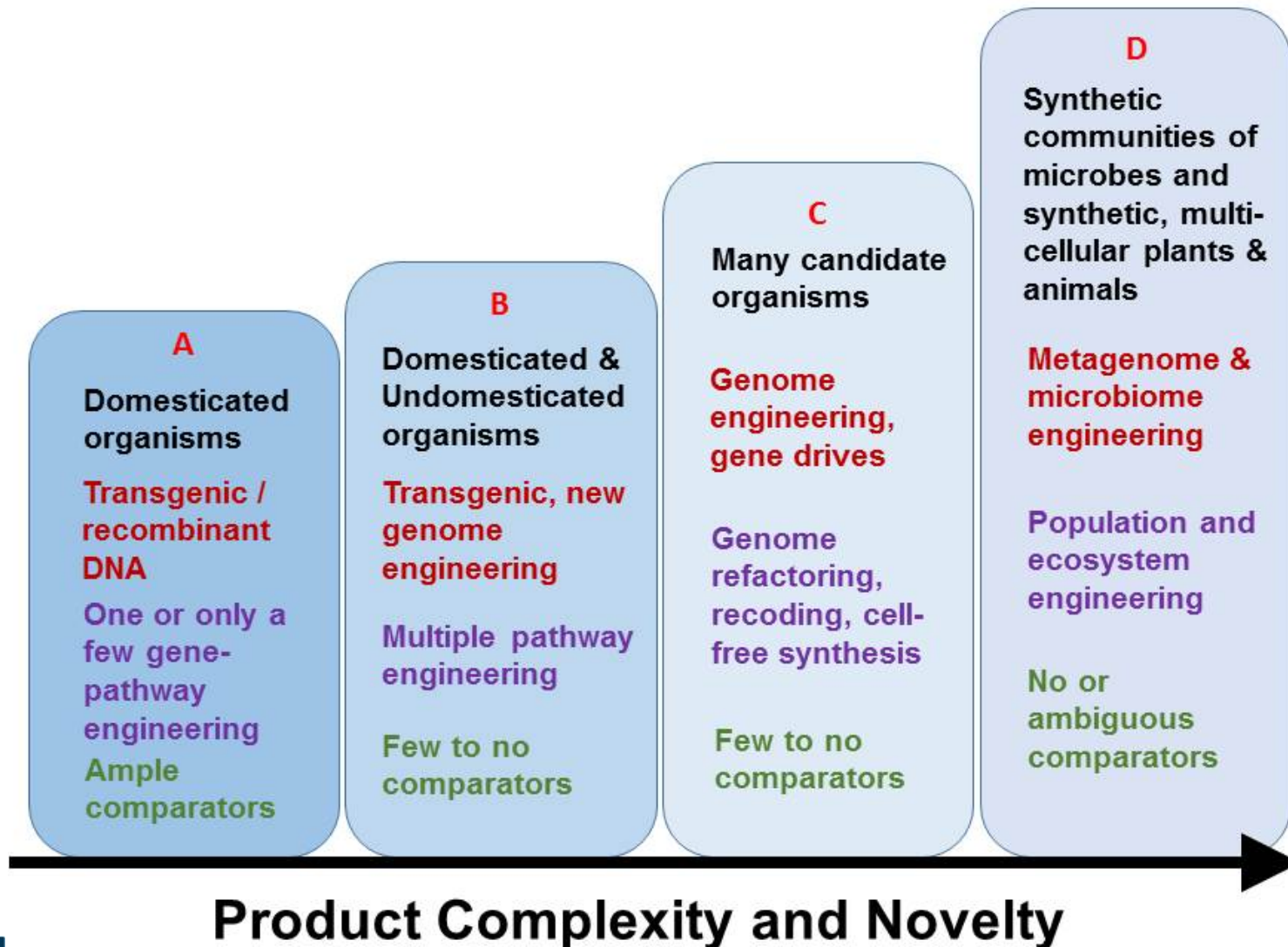
## Open release products



“Platforms”  
(products used to make other products)



# New products will be unfamiliar and complex



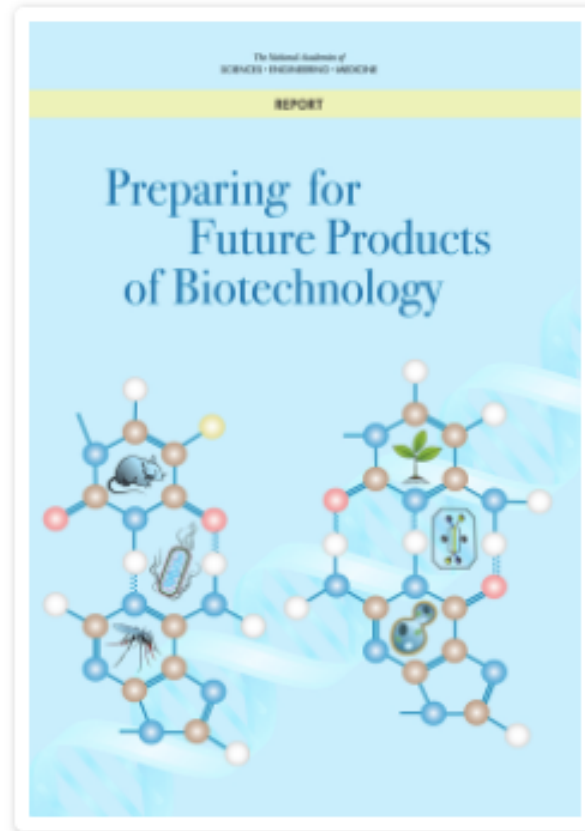
# Emergent Themes of the Study

- The bioeconomy is growing rapidly and the U.S. regulatory system needs to provide a *balanced approach* for consideration of the many stakeholders and competing interests in the face of this expansion
- The *profusion* of biotechnology products over the next 5-10 years has the *potential to overwhelm* the U.S. regulatory system
- Regulators will face *difficult challenges* that go *beyond contained industrial uses and traditional environmental release, including new “players”*
- The safe use of new biotechnology products requires *rigorous, predictable, and transparent risk-analysis processes* that *mirror the scope, scale, complexity, and tempo* of biotechnology development

*The National Academies of*

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So...regulatory systems need to be adaptable!



[www.nap.edu/catalog/24605/preparing-for-future-products-of-biotechnology](http://www.nap.edu/catalog/24605/preparing-for-future-products-of-biotechnology)

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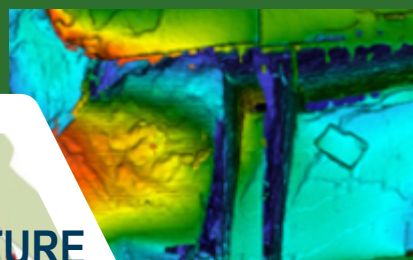
# Berkeley Lab-wide Strategic Priorities 2018



BIOLOGICAL and  
ENVIRONMENTAL  
SCIENCE at the  
BIOCAMPUS



BREAKTHROUGH  
SCIENCE  
at the EXASCALE



The Ecosystem Manipulatory

ecoFAB ecoTECH ecoSENSE ecoSIM

INFRASTRUCTURE  
RENEWAL



SCIENCE with  
THE UPGRADED  
ADVANCED LIGHT SOURCE



DISCOVERY SCIENCE  
in FUNDAMENTAL  
PHYSICS





# Berkeley Lab Infrastructure Priorities

## Future BioCampus

### JBEI+ (envisioned)

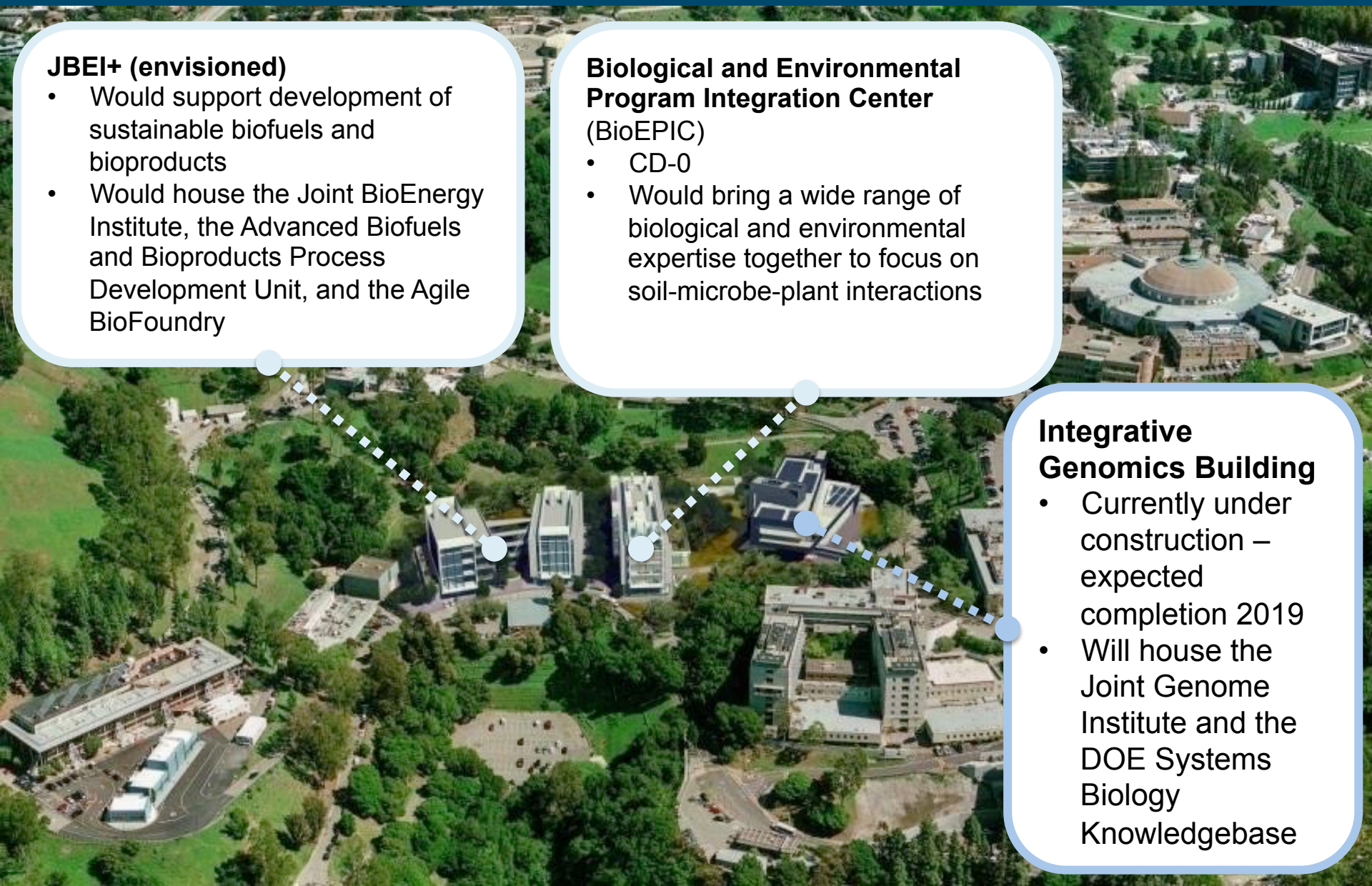
- Would support development of sustainable biofuels and bioproducts
- Would house the Joint BioEnergy Institute, the Advanced Biofuels and Bioproducts Process Development Unit, and the Agile BioFoundry

### Biological and Environmental Program Integration Center (BioEPIC)

- CD-0
- Would bring a wide range of biological and environmental expertise together to focus on soil-microbe-plant interactions

### Integrative Genomics Building

- Currently under construction – expected completion 2019
- Will house the Joint Genome Institute and the DOE Systems Biology Knowledgebase





# Questions?

